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GATE SOLVED PAPER - EE

2015-2

General Aptitude

Q. 1 - Q. 5 Carry one mark each.

Q. 1 A generic term that includes various items of clothing such as a skirt, a pair of trousers and a shirt as

(A) fabric (B) textile

(C) fibre (D) apparel

Sol. 1 Correct option is (D).

The words given in the options are defined below.

(A) Fabric – artifact made by weaving or felting or knitting or crocheting natural or synthetic fibres.

(B) Textile- textile and fabric are synonym

(C) Fibre – a leather like material made by compressing layers of paper or cloth.

(D) apparel – clothing in general

Thus, *apparel* is the generic term that includes various items of clothing such as a skirt, a pair of trousers and a shirt.

Q. 2 Choose the statement where underlined word is used correctly.

(A) The industrialist had a personnel jet.

(B) I write my experience in my personnel diary.

(C) All personnel are being given the day off.

(D) Being religious is a personnel aspect.

Sol. 2 Correct option is (C).

In options (A), (B), (D), *personnel* is used in wrong way. Here, according to sentences, *personal* should be used. The difference in the meaning between two words are

Personal: particular to a given individual

Personnel: group of people willing to obey orders

Hence, the statement given in option (C) is correct.

Q. 3 Based on the given statements, select the most appropriate option to solve the given question.

What will be the total weight of 10 poles each of same weight?

Statements:

(I) One fourth of the weight of a pole is 5 kg.

(II) The total weight of these poles is 160 kg more than the total weight of two poles.

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(A) Statement I alone is not sufficient

(B) Statement II alone is not sufficient

(C) Either I or II alone is sufficient

(D) Both statements I and II together are not sufficient.

Sol. 3 Correct option is (C).

The given problem requires the total weight of 10 poles, each of same weight. We check the given statements for evaluation of the total weight.

Statement I

Given that one forth of weight of a pole is 5 kg.

Let weight of a pole $= x$ kg

So, $\frac{x}{4} = 5$

$x = 20$ kg

Hence, total weight of 10 poles $= 10x$

$= 200$ kg

Statement II

The total weight of 10 poles is 160 kg more than the total weight of two poles.

Let weight of a pole $= x$ kg

So, total weight of 10 poles $= 10x$

Therefore, $10x = 2x + 160$

$8x = 160$

$x = 20$ kg

Hence, total weight of 10 poles $= 10x$

$= 20 \times 10 = 200$ kg

Thus, the given problem can be solved by using any of the two statements.

Q. 4 Consider a function $f(x) = 1 - |x|$ on $-1 \le x \le 1$. The value of x at which the function attains a maximum, and the maximum value of function are

(A) $0, -1$

(B) $-1, 0$

(C) 0, 1

(D) $-1, 2$

Sol. 4 Correct option is (C).

Given $f(x) = 1 - |x|$ $\quad -1 \le x \le 1$

Since, $|x| > 0$, for all x

So, $|x|$ can take minimum value of 0 and maximum value of 1. Also, on increasing value of $|x|$, value of $f(x)$ decreases. At $|x| = 0$, we obtain

$f(x) = 1 - |x|$

$= 1 - 0 = 1$ (function has maximum value)

Again, at $|x| = 1$, we obtain

$f(x) = 1 - |x|$

$= 1 - 1 = 0$ (function has minimum value)

Thus, at $|x| = 0$ value of $f(x)$ is maximum and at $|x| = 1$ value of $f(x)$ is minimum.

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Q. 5 We _____ our friend's birthday and we _____ how to make it up to him.

(A) completely forgot _____ don't just know

(B) forget completely _____ don't just know

(C) completely forget _____ just don't know

(D) forgot completely _____ just don't know

Sol. 5 Correct option is (C).

In first blank, adverb should be used before the verb, i.e.

completely forgot

Again, in second blank, adverb should be used before the verb. We must note that adverb is not being used in between the auxiliary verb, i.e.

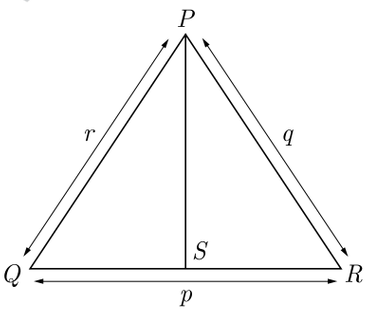
just don't know

Thus, the complete sentence is

We completely forgot our friend's birthday and we just don't know how to make it up to him.

Q. 6 - Q. 10 Carry two marks each.

Q. 6 In a triangle PQR, PS is the angle bisector of $\angle QPR$ and $\angle QPS = 60^\circ$. What is the length of PS?



(A) $\dfrac{(q+r)}{qr}$

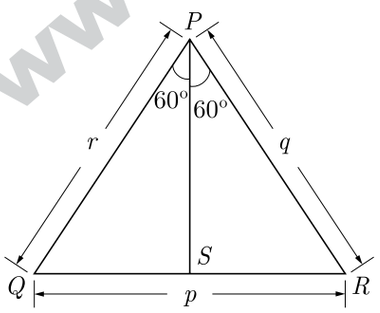
(B) $\dfrac{qr}{(q+r)}$

(C) $\sqrt{(q^2+r^2)}$

(D) $\dfrac{(q+r)^2}{qr}$

Sol. 6 Correct option is (B).

We redraw the triangle as



In triangle, the internal bisector of an angle bisect the opposite side in the ratio of the other two sides. So, we have

$$\frac{QS}{SR} = \frac{PQ}{PR}$$

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$$\frac{QS}{SR} = \frac{r}{q}$$

$$\frac{QS+SR}{SR} = \frac{r+q}{q}$$

$$\frac{SR}{QR} = \frac{q}{r+q}$$

$$SR = \frac{qp}{r+q} \qquad ...(2)$$

By using cosine formula in triangle $\triangle PSR$,

$$\cos 60^\circ = \frac{(PR)^2+(PS)^2-(SR)^2}{(PR)(PS)}$$

or
$$\frac{1}{2} = \frac{q^2+(PS)^2-\left(\frac{qp}{r+q}\right)^2}{q\times(PS)}$$

Hence,
$$PS = \frac{qr}{r+q}$$

Q. 7 Four branches of a company are located at M, N, O and P. M is north of N at a distance of 4 km; P is south of O at a distance of 2 km; N is southeast of O by 1 km. What is the distance between M and P in km?

(A) 5.34

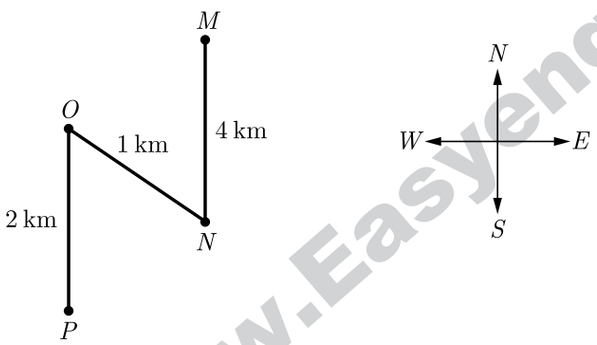
(B) 6.74

(C) 28.5

(D) 45.49

Sol. 7 Correct option is (A).

From the given data, we draw the schematic as



Let coordinate of $N = (0,0)$

coordinate of $M = (0,4)$

coordinate of $O = \left(-\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}\right)$

coordinate of $P = \left(-\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}} - 2\right)$

Hence, by distance formula, we obtain

$$MP = \sqrt{(x_1-x_2)^2+(y_1-y_2)^2}$$

$$= \sqrt{\left(0+\frac{1}{\sqrt{2}}\right)^2+\left(4+2-\frac{1}{\sqrt{2}}\right)^2}$$

$$= 5.34 \text{ km}$$

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Q. 8 If p, q, r, s are distinct integers such that:

$$f(p,q,r,s) = \max(p,q,r,s)$$
$$g(p,q,r,s) = \min(p,q,r,s)$$
$$h(p,q,r,s) = \text{remainder of } \frac{(p \times q)}{(r \times s)} \text{ if } (p \times q) > (r \times s)$$
$$\text{or remainder of } \frac{(r \times s)}{(p \times q)} \text{ if } (r \times s) > (p \times q)$$

Also, a function

$$fgh(p,q,r,s) = f(p,q,r,s) \times g(p,q,r,s) \times h(p,q,r,s)$$

Also the same operations are valid with two variable function of the form $f(p,q)$. What is the value of $fg(h(2,5,7,3),4,6,8)$?

Sol. 8 Correct answer is 8.

Here, we have to determine the value of $fg(h(2,5,7,3),4,6,8)$.

Given $h(p,q,r,s) = \text{remainder of } \frac{(p \times q)}{(r \times s)} \text{ if } (p \times q) > (r \times s)$

$$\text{or remainder of } \frac{(r \times s)}{(p \times q)} \text{ if } (r \times s) > (p \times q)$$

So, we obtain

$$h(2,5,7,3) \text{ remainder } \left(\frac{7 \times 3}{2 \times 5}\right) \qquad (\text{since } (7 \times 3) > (2 \times 5))$$
$$= 1$$

Therefore, we get

$$fg(h(2,5,7,3),4,6,8) = fg(1,4,6,8)$$

Again, we have

$$f(p,q,r,s) = \max(p,q,r,s)$$
$$g(p,q,r,s) = \min(p,q,r,s)$$

So, we obtain

$$fg(1,4,6,8) = f(1,4,6,8) \times g(1,4,6,8)$$
$$= \max(1,4,6,8) \times \min(1,4,6,8)$$
$$= 8 \times 1$$
$$= 8$$

Hence, the value of desired function is

$$fg(h(2,5,7,3),4,6,8) = fg(1,4,6,8) = 8$$

Q. 9 If the list of letters P, R, S, T, U is an arithmetic sequence, which of the following are also in arithmetic sequence?

(I) $2P, 2R, 2S, 2T, 2U$

(II) $P-3, R-3, S-3, T-3, U-3$

(III) P^2, R^2, S^2, T^2, U^2

(A) I only (B) I and II

(C) II and III (D) I and III

Sol. 9 Correct option is (B).

Here, P, R, S, T, U are in A.P. So, the difference between two consecutive numbers will be equal, i.e.

$$d = R - P = S - R = T - S = U - T$$

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where d is common difference for the given A.P. Now, we check the given sequences

Sequence I

$2P$, $2R$, $2S$, $2T$, $2U$

The differences between two consecutive numbers are obtained as

$$D = 2R - 2P = 2(R - P) = 2d$$
$$D = 2S - 2R = 2(S - R) = 2d$$
$$D = 2T - 2S = 2(T - S) = 2d$$

Since, the differences are same in each case, so it is in A.P.

Sequence II

$P-3$, $R-3$. $S-3$, $T-3$, $V-3$

The differences between two consecutive numbers are obtained as

$$D = (R-3) - (P-3)$$
$$= R - P - 3 + 3 = R - P = d$$
$$D = (S-3) - (R-3)$$
$$= S - R - 3 + 3 = S - R = d$$

Again, the differences are same in each case, so it is in A.P.

Sequence III

P^2, R^2, S^2, T^2, V^2

The differences between two consecutive numbers are obtained as

$$D = R^2 - P^2 = (R - P)(R + P)$$
$$= d \times (R + P)$$
$$D = S^2 - R^2 = (S - R)(S + R)$$
$$= d \times (S + R)$$

In this case, the differences are not same, so it is not in A.P.

Thus, sequences I and II will be in A.P.

Q. 10 Out of the following four sentence, select the most suitable sentence with respect to grammar and usage:

(A) Since the report lacked needed information, it was of no use to them.

(B) The report was useless to them because there were no needed information in it.

(C) Since the report did not contain the needed information, it was not real useful to them.

(D) Since the report lacked needed information, it would not had been useful to them.

Sol. 10 Correct option is (A).

END OF THE QUESTION PAPER

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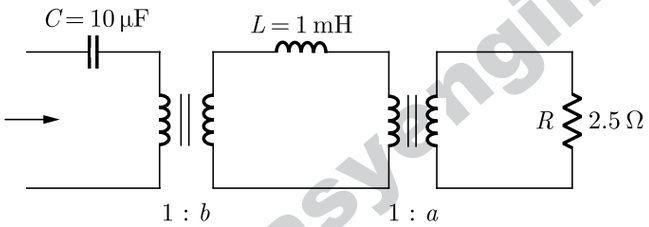
Electrical Engineering

Q. 1 - Q. 25 Carry one mark each.

Q. 1 Find the transformer ratios a and b that the impedance (Z_{in}) is resistive and equal $2.5\,\Omega$ when the network is excited with a sine wave voltage of angular frequency of 5000 rad/s.



(A) $a = 0.5, b = 2.0$ (B) $a = 2.0, b = 0.5$

(C) $a = 1.0, b = 1.0$ (D) $a = 4.0, b = 0.5$

Sol. 1 Correct option is (B).

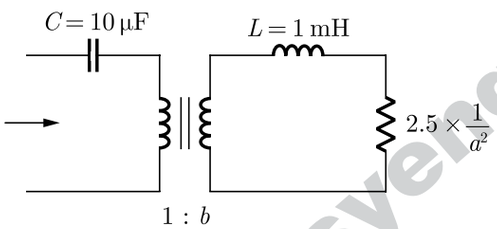
Given

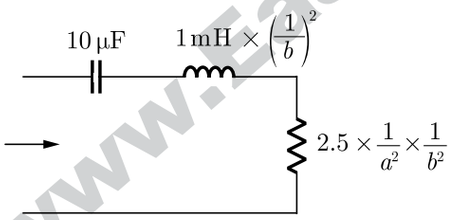
$$Z_{in} = 2.5\,\Omega \text{ (resistive)}$$

$$\omega = 5000 \text{ rad/sec}$$

Now, we transform the impedance in primary side by using the formula

$$Z_1 = Z_2\left(\frac{N_1}{N_2}\right)^2$$





Since, input impedance is purely resistive $(Z_{in} = 2.5\,\Omega)$, so

$$2.5 \times \frac{1}{a^2 b^2} = 2.5$$

$$ab = 1 \qquad \ldots(1)$$

Also, the reactance is zero, i.e.

$$\omega L - \frac{1}{\omega C} = 0$$

$$5000 \times 1 \times 10^{-3}\left(\frac{1}{b^2}\right) = \frac{1}{5000 \times 10 \times 10^{-6}}$$

$$\frac{5}{b^2} = \frac{1}{5 \times 10^{-2}}$$

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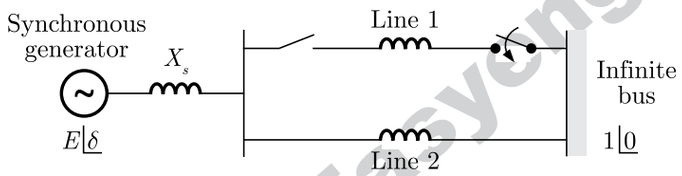
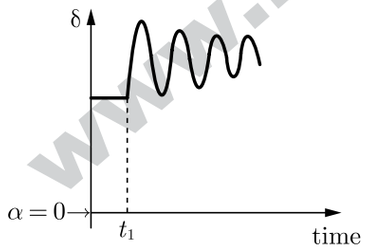
Hence, $b = 0.5$

and $a = 2$

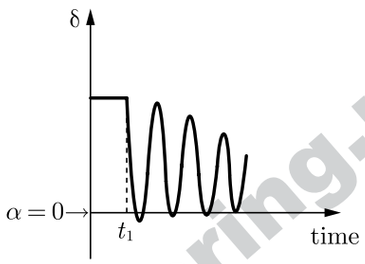
Q. 2 The synchronous generator shown in the figure is supplying active power to an infinite bus via two short, lossless transmission lines, and is initially in steady state. The mechanical power input to the generator and the voltage magnitude E are constant. If one line is tripped at time t_1 by opening the circuit breakers at two ends (although there is no fault), then it is seen that the generator undergoes a stable transient. Which one of the following waveforms of the rotor angle δ shows the transient correctly ?



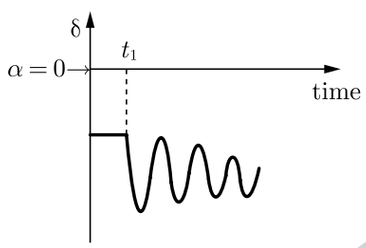
(A)



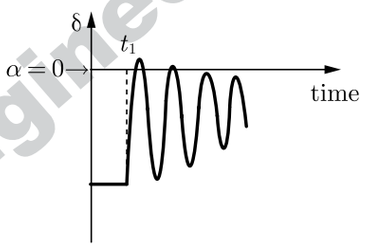
(B)



(C)



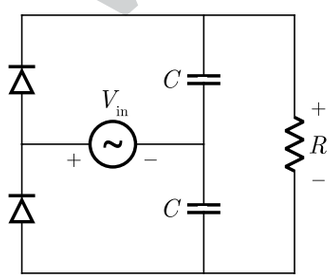
(D)



Sol. 2 Correct option is (A).

Since, it is generator, so rotor angle δ is also positive. So, options (C) and (D) are incorrect. Again, if one line is tripped, then due to unstable operation of generator, δ increases. Waveform shown in option (A) satisfies the condition.

Q. 3 In the following circuit, the input voltage V in $100\sin(100\pi t)$. For $100\pi RC = 50$, the average voltages across R (in volts) under steady-state is nearest to



(A) 100

(B) 31.8

(C) 200

(D) 63.6

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Sol. 3 Correct option is (C).

Time period of sinusoidal voltage is

$$T = \frac{2\pi}{100\pi}$$

$$= \frac{1}{50} = 20 \text{ ms}$$

Time constant of circuit is

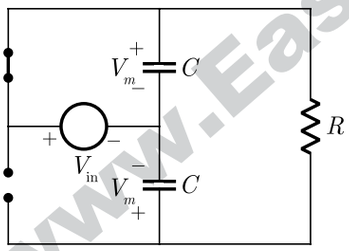
$$\tau = RC = \frac{50}{100\pi} = \frac{1}{2\pi} \text{ sec.}$$

So, we observe that

$$\tau >> T$$

or Time constant >> Time period

For the first half cycle, we have the circuit as



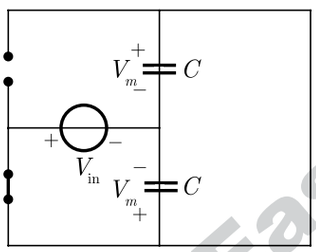
After charging, it will not discharge immediately, so voltage across resistance R is

$$= 2\,V_m$$

$$= 2 \times 100$$

$$= 200 \text{ V}$$

Again, for the second half cycle, circuit becomes as



In second half cycle also, voltage across resistance R is

$$= 2\,V_m$$

$$= 2 \times 100$$

$$= 200 \text{ V}$$

Q. 4 A 4-pole, separately excited, wave wound DC machine with negligible armature resistance is rated for 230 V and 5 kW at a speed of 1200 rpm. If the same armature coils are reconnected to forms a lap winding. What is the rated voltage (in volts) and power (in kW) respectively at 1200 rpm of the reconnected machine if the field circuit is left unchanged?

(A) 230 and 5 (B) 115 and 5

(C) 115 and 2.5 (D) 230 and 2.5

Sol. 4 Correct option is (B).

For the separately excited dc machine (wave wound), we have

$$\text{Rating} = 230 \text{ V and } 5 \text{ kW}$$

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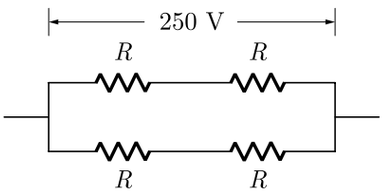
$$\text{Speed} = 1200 \text{ rpm}$$

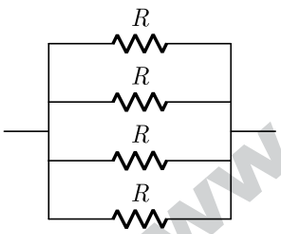
$$\text{Pole} = 4$$

In wave, number of parallel path is 2.



So, $$R = \frac{V^2}{P} = \frac{(230)^2}{5}$$

Now, it is connected in lap for which we have to determine the rating.



So, the voltage will reduce to its half value, i.e.

$$V_{\text{lap}} = \frac{230}{2} = 115 \text{ V}$$

and current will be double. Hence, power of the machine will be same, i.e.

$$P_{\text{lap}} = 5 \text{ kW}$$

Q. 5 Given $f(z) = g(z) + h(z)$, where f, g, h are complex valued functions of a complex variable z. Which one of the following statements is TRUE ?

(A) If $f(z)$ is differential at z_0, then $g(z)$ and $h(z)$ are also differentiable at z_0.

(B) If $g(z)$ and $h(z)$ are differentiable at z_0, then $f(z)$ is also differential at z_0.

(C) If $f(z)$ is continuous at z_0, then it is differential at z_0.

(D) If $f(z)$ is differentiable at z_0, then so are its real and imaginary parts.

Sol. 5 Correct option is (B).

Given $f(z) = g(z) + h(z)$

Let $g(z) = gu(z) + jgv(z)$

and $h(z) = hu(z) + jhv(z)$

If g and h are differentiable, then it will satisfy L-R equation. So, we have

$$gu_x = gv_y,\ gu_y = -gv_x$$

and $$hu_x = hv_y,\ hu_y = -hv_x$$

Therefore, $$f(z) = \big(gu(z) + hu(z)\big) + j\big(gv(z) + hv(z)\big)$$

By observing the above equations, we get

$$(gu_x + hu_x) = (gv_y + hv_y) \quad \ldots(1)$$

$$(gu_y + hu_y) = -(gv_x + hv_x) \quad \ldots(2)$$

Hence, from equations (1) and (2), $f(z)$ is differentiable (because it satisfies L-R equation).

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Q. 6 A 3-bus power system network consists of 3 transmission lines. The bus admittance matrix of the uncompensated system is

$$\begin{bmatrix} -j6 & j3 & j4 \\ j3 & -j7 & j5 \\ j4 & j & -j8 \end{bmatrix} \text{pu}$$

If the shunt capacitance of all transmissions line is 50% compensated, the imaginary part of the 3rd row 3rd column element (in pu) of the bus admittance matrix after compensation is

(A) $-j7.0$

(B) $-j8.5$

(C) $-j7.5$

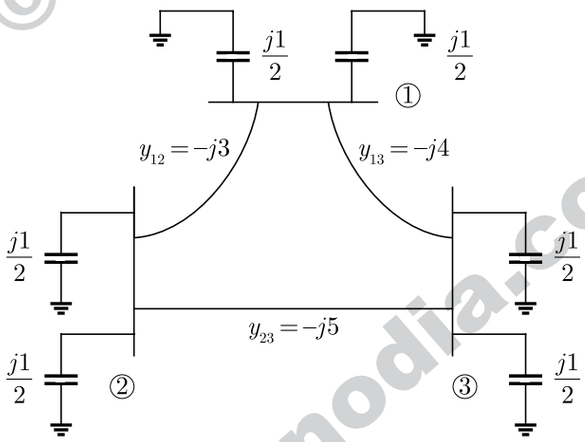
(D) $-j9.0$

Sol. 6 Correct option is (B).

Given bus admittance matrix,

$$Y_{\text{BUS}} = \begin{bmatrix} -j6 & j3 & j4 \\ j3 & -j7 & j5 \\ j4 & j & -j8 \end{bmatrix}$$

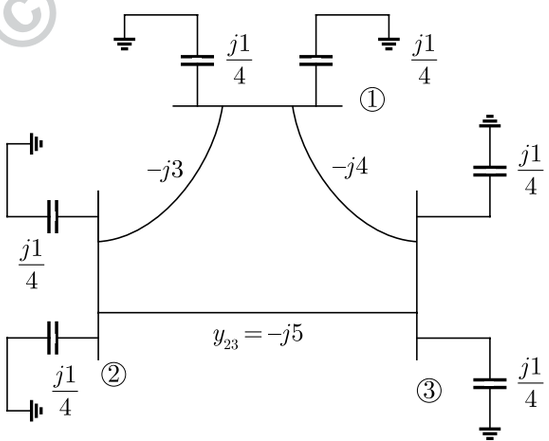
For the given data, we draw the schematic as



If shunt capacitance of all transmission line is 50% compensated, then $y_{sh} = j1/2$ reduces to its half value, i.e.

$$y_{sh(\text{new})} = \frac{j1}{4}$$

Therefore, the system becomes as



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Hence, we get

$$\begin{aligned} y_{33} &= y_{23} + y_{13} + y_{13(\text{shunt})} + y_{23(\text{shunt})} \\ &= -j4 - j5 + j\frac{1}{4} + j\frac{1}{4} \\ &= -j8.5 \end{aligned}$$

Q. 7 A shunt-connected DC motor operates at its rated terminal voltage. Its no-load speed is 200 radians/second. At its rated torque of 500 Nm, its speed is 180 radian/second. The motor is used to directly drive a load whose load torque T_L depends on its rotational speed (in radians/second), such that $T_L = 2.78 \times \omega_r$. Neglecting rotational losses, the steady-state speed (in radian/second) of the motor, when it drives this load is_____

Sol. 7 Correct answer is 178.8

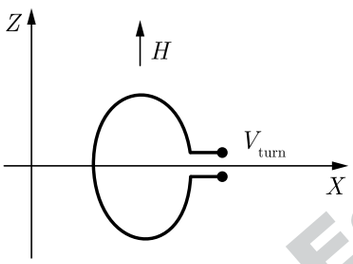
For the shunt connected dc motor,

$$T_L = 2.78\omega_r$$

Under steady state, we have

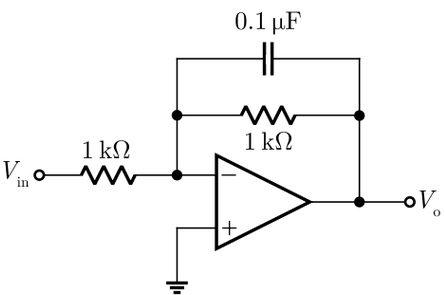
$$\begin{aligned} \text{Load torque} &= \text{Rotated torque} \\ 2.78 \times \omega_r &= 500 \\ \omega_r &= \frac{500}{2.78} \\ &= 178.88 \text{ rad/sec} \end{aligned}$$

Q. 8 A circular turn of radius 1 m revolves at 60 rpm about its diameter aligned with the x-axis as shown in the figure. The value of μ_0 is $4\pi \times 10^{-7}$ in SI unit. If a uniform magnetic field intensity $\overline{H} = 10^7 \hat{z}$ A/m is applied, then the peak value of the inducted voltage, V_{turn} (in volts), is _____



Sol. 8 Correct answer is 246 to 250.

Q. 9 The operational amplifier shown in the figure is ideal. The input voltage (in volt) is $V_i = 2\sin(2\pi \times 2000t)$ The amplitude of the output voltage V_0 (in Volt) is_____



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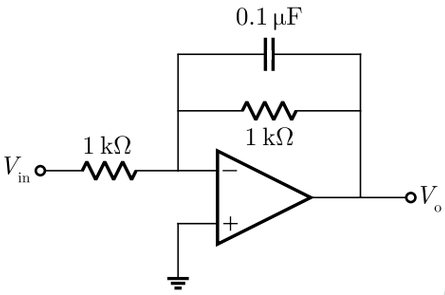
Sol. 9 Correct answer is 1.245

Given op-amp circuit is



From the circuit, we have

$$V_o = -\frac{Z_2}{Z_1} V_i \qquad ...(1)$$

where $Z_1 = 1\,\text{k}\Omega$

and $$Z_2 = \frac{R_2 \times \frac{1}{Cs}}{\frac{1}{Cs} + R_2}$$

$$= \frac{R_2}{R_2 Cs + 1} = \frac{1 \times 10^3}{1 \times 10^3 \times 0.1 \times 10^{-6} + 1}$$

$$= \frac{1 \times 10^3}{10^{-4} s + 1} = \frac{1 \times 10^3}{j\omega 10^{-4} + 1}$$

$$|Z_2| = \frac{1 \times 10^3}{j \times 2\pi \times 2000 \times 10^{-4} + 1}$$

$$= 622.67$$

Hence, substituting it in equation (1), we get

$$V_o = -\frac{Z_2}{Z_1} V_i$$

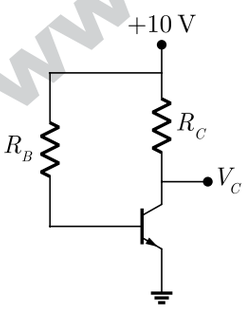
$$= \frac{622.67}{1 \times 10^3} \times 2\sin(2\pi \times 2000t)$$

$$= 1.245\sin(2\pi \times 2000t)$$

Thus, the amplitude of output voltage is

$$|V_o| = 1.245$$

Q. 10 In the following circuit, the transistor is in active mode and $V_C = 2$ V. To get $V_C = 2$ V. To get $V_C = 4$ V, we replace R_C with R_C'. Then the ratio R_C'/R_C is_____



Sol. 10 Correct answer is 0.75

Given $V_C = 2\,\text{V}$

From the circuit, we have

$$V_C = V_{CC} - I_C R_C$$

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So, $2 = V_{CC} - I_C R_C$

or $I_C R_c = 10 - 2 = 8 \text{ V}$

Now, to get $V_C = 4 \text{ V}$, we replace R_C with R_C'. So,

$$V_C = V_{CC} - I_C R_C'$$

or $I_c R_C' = 10 - 4 = 6 \text{ V}$

Hence, $\dfrac{R_C'}{R_C} = \dfrac{6}{8} = 0.75$

Q. 11 The Laplace transform of $f(t) = 2\sqrt{\dfrac{t}{\pi}}$ is $s^{-3/2}$. The Laplace transform of $g(t) = \sqrt{\dfrac{1}{\pi t}}$ is

(A) $\dfrac{3s^{-5/2}}{2}$

(B) $s^{-1/2}$

(C) $s^{1/2}$

(D) $s^{3/2}$

Sol. 11 Correct option is (B).

Given function,

$$f(t) = 2\sqrt{\frac{t}{\pi}}$$

and its Laplace transform,

$$L(f(t)) = s^{-3/2}$$

Now, we define

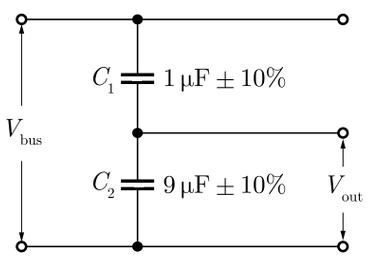
$$g(t) = \frac{1}{\sqrt{\pi t}} = \frac{1}{2}\frac{f(t)}{t}$$

So, $$L(g(t)) = \frac{1}{2}L\left(\frac{f(t)}{t}\right) = \frac{1}{2}\left(\int_s^\infty s^{-3/2}\, ds\right)$$

$$= \frac{1}{2} \times \left[\frac{s^{-\frac{3}{2}+1}}{-\frac{1}{2}}\right]_s^\infty = \left[s^{-1/2}\right]_\infty^s = s^{-1/2} - 0$$

Hence, $L(g(t)) = s^{-1/2} = \dfrac{1}{\sqrt{s}}$

Q. 12 A capacitive voltage divider is used to measure the bus voltage V_{bus} in a high-voltage 50 Hz AC system as shown in the figure. The measurement capacitor C_1 and C_2 have tolerance of $\pm 10\%$ on their normal capacitance values. If the bus voltage V_{bus} is 100 kV rms, the maximum rms output voltage V_{out} (in kV), considering the capacitor tolerance, is_____



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Sol. 12 Correct answer is 11.95

From the given circuit, we have

$$V_{\text{out}} = \left(\frac{X_{C_2}}{X_{C_1} + X_{C_2}}\right) \times V_{\text{bus}}$$

$$= \left(\frac{\frac{1}{\omega C_2}}{\frac{1}{\omega C_1} + \frac{1}{\omega C_2}}\right) \times V_{\text{bus}}$$

$$= \frac{\frac{1}{C_2}}{\left(\frac{1}{C_1} + \frac{1}{C_2}\right)} \times V_{\text{bus}}$$

$$V_{\text{out}} = \left(\frac{C_1}{C_1 + C_2}\right) \times V_{\text{bus}}$$

For maximum value of V_{out}, C_1 is maximum and C_2 is minimum. Hence,

$$V_{\text{out(max)}} = \frac{(1.1)}{(1.1 + 8.1)} \times 100$$

$$= 11.95 \text{ V}$$

Q. 13 Match the following

P	Stokes's Theorem	1	$\oiint D \cdot ds = Q$
Q	Gauss's Theorem	2	$\oint f(z)\,dx = 0$
R	Divergence Theorem	3	$\iiint (\nabla \cdot A)\,dv = \oiint A.ds$
S	Cauchy's Integral Theorem	4	$\iint (\nabla \times A).ds = \oint A.dl$

(A) P-2, Q-1, R-4, S-3 (B) P-4, Q-1, R-3, S-2

(C) P-4, Q-3, R-1, S-2 (D) P-3, Q-4, R-2, S-1

Sol. 13 Correct option is (B).

In vector calculus, some important theorems are defined as follows:

Strokes theorem

$$\iint (\nabla \times A)\,ds = \oint A \cdot dl$$

Divergence theorem

$$\iiint (\nabla \cdot A)\,dv = \oiint A \cdot ds$$

Gauss theorem

$$\oiint D \cdot ds = Q$$

Cauchy integral theorem

$$\oint f(z)\,dz = 0$$

Q. 14 Consider the following Sum of products expression, F.

$$F = ABC + \overline{A}\overline{B}C + A\overline{B}C + \overline{A}BC + \overline{A}\overline{B}\overline{C}$$

The equivalent product of Sums expression is

(A) $F = (A + \overline{B} + C)(\overline{A} + B + C)(\overline{A} + \overline{B} + C)$

(B) $F = (A + B + \overline{C})(A + B + C)(\overline{A} + \overline{B} + \overline{C})$

(C) $F = (\overline{A} + B + \overline{C})(A + \overline{B} + \overline{C})(A + B + C)$

(D) $F = (\overline{A} + \overline{B} + C)(A + B + \overline{C})(A + B + C)$

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Sol. 14 Correct option is (A).

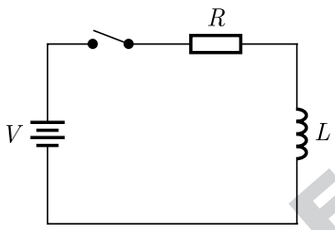
Given minterm,

$$F = \Sigma m(0,1,3,5,7)$$

So, product of sums representation is

$$F = \Pi m(2,4,6)$$
$$= (A + \overline{B} + C)(\overline{A} + B + C)(\overline{A} + \overline{B} + C)$$

Q. 15 A series RL circuit is excited at $t = 0$ by closing a switch as shown in the figure. Assuming zero initial conditions, the value of $\frac{d^2 i}{dt^2}$ at $t = 0^+$ is



(A) $\frac{V}{L}$ (B) $\frac{-V}{R}$

(C) 0 (D) $\frac{-RV}{L^2}$

Sol. 15 Correct option is (D).

For the given circuit,

$$i = i(0^+)(1 - e^{-t/\tau}) \qquad (\tau = L/R)$$
$$i = \frac{V}{R}\left(1 - e^{-\frac{Rt}{L}}\right)$$
$$\frac{di}{dt} = \frac{V}{R}\frac{R}{L}e^{-\frac{Rt}{L}}$$
$$\frac{d^2 i}{dt^2} = -\frac{VR}{L^2}e^{-\frac{Rt}{L}}$$

Hence, at $t = 0^+$, we get

$$\frac{d^2 i}{dt^2} = -\frac{VR}{L^2}$$

Q. 16 We have a set of 3 linear equations in 3 unknowns. '$X \equiv Y$' means X and Y are equivalent statements and '$X \not\equiv Y$' means X and Y are not equivalent statements.

P: There is a unique solution.

Q: The equations are linearly independent.

R: All eigenvalues of the coefficient matrix are nonzero.

S: The determinant of the coefficient matrix is nonzero.

Which one of the following is TRUE?

(A) P $\equiv$ R $\equiv$ Q $\equiv$ S

(B) P $\equiv$ R $\not\equiv$ Q $\equiv$ S

(C) P $\equiv$ Q $\not\equiv$ R $\equiv$ S

(D) P $\not\equiv$ Q $\not\equiv$ R $\not\equiv$ S

Sol. 16 Correct option is (A).

If determinant of coefficient matrix is non-zero then there is a unique solution. If determine is non-zero, so all the eigen value are non-zero. If eigen values are non-zero then equation are linearly independent.

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Q. 17 Match the following :

	Instrument Type		Used For
P	Permanent Magnet moving coil	1	DC only
Q	Moving iron connected through current transformer	2	AC only
R	Rectifier	3	AC and DC
S	Electrodynamometer	4	

(A) P-1 Q-2 R-1 S-3 (B) P-1 Q-3 R-1 S-2

(C) P-1 Q-2 R-3 S-3 (D) P-3 Q-1 R-2 S-1

Sol. 17 Correct option is (C).

The working of instruments are defined below.

P. PMMC: Only for D.C. only because if given only average value.

Q. Moving Iron: Used only for A.C. because of current transformer is connected because, for D.C. it is saturated.

R. Rectifier: Used for A.C. and D.C. both

S. Electrodynamometer: It is also used for A.C. and D.C. both.

Q. 18 Two semi-infinite dielectric regions are separated by a plane boundary at $y = 0$. The dielectric constant of region $1(y < 0)$ and region $2(y > 0)$ are 2 and 5, region 1 has uniform electric field $\overline{E} = 3\hat{a}_x + 4\hat{a}_y + 2\hat{a}_z$, where $\hat{a}_x$, $\hat{a}_y$, and $\hat{a}_z$ are unit vectors along the x, y and z axes, respectively. The electric filed region 2 is

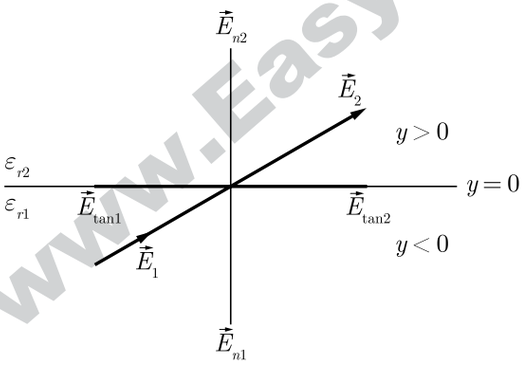
(A) $3\hat{a}_x + 1.6\hat{a}_y + 2\hat{a}_z$ (B) $1.2\hat{a}_x + 4\hat{a}_y + 2\hat{a}_z$

(C) $1.2\hat{a}_x + 4\hat{a}_y + 0.8\hat{a}_z$ (D) $3\hat{a}_x + 10\hat{a}_y + 0.8\hat{a}_z$

Sol. 18 Correct option is (A).

Given dielectric constant of the two mediums,

$$\varepsilon_{r1} = 1 \ , \ \varepsilon_{r2} = 5$$



From the figure, we have

$$\vec{E}_{\tan 1} = \vec{E}_{\tan 2}$$

For $y = 0$ plane, tangential component is along x and z direction. So, we get

$$E_{x1}\hat{a}_x + E_{z1}\hat{a}_z = E_{x2}\hat{a}_x + E_{z2}j\hat{a}_z$$

$$3\hat{a}_x + 2\hat{a}_z = E_{x2}\hat{a}_x + E_{z2}\hat{a}_z$$

Again, we have

$$D_{n1} = D_{n2}$$

$$\varepsilon_1 E_{n1} = \varepsilon_2 E_{n2}$$

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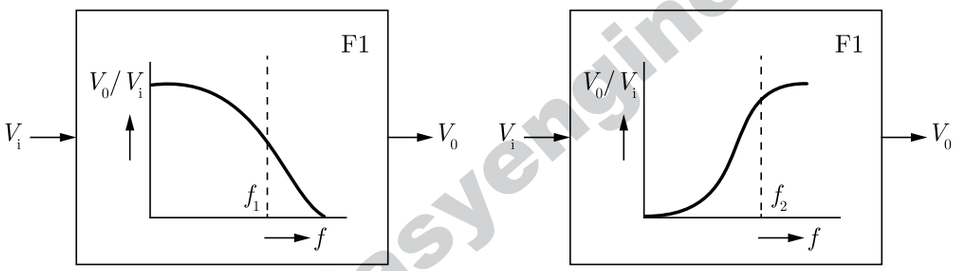
$$\frac{2}{5} \times 4 = E_{n2}$$

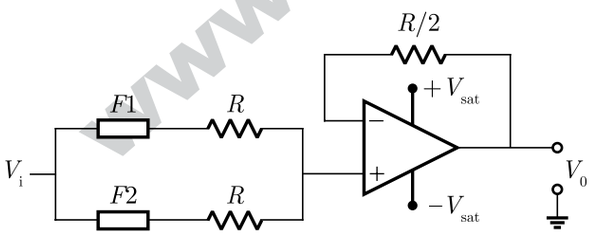
$$\vec{E}_{n2} = 1.6\hat{a}_y$$

Hence, $$\vec{E}_2 = 3\hat{a}_x + 1.6\hat{a}_y + 2\hat{a}_z$$

Q. 19 The filters F_1 and F_2 having characteristics as shown in Figures (a) and (b) are connected as shown in Figure (c).



(a) (b)



(c)

The cut-off frequencies of F_1 and F_2 are f_1 and f_2 respectively. If $f_1 < f_2$, the resultant circuit exhibits the characteristics of a

(A) Band-pass filter

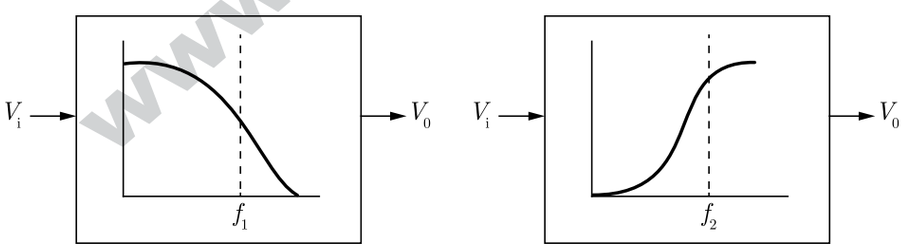
(B) Band-stop filter

(C) All pass filter

(D) High-Q-filter

Sol. 19 Correct option is (B).

Given characteristic curve for the two filters,



(a) (b)

In the given figure, (a) is low pass filter and (b) is high pass filter. Also, we have

$$f_1 < f_2$$

For $f < f_1$, we have the op-amp circuit as

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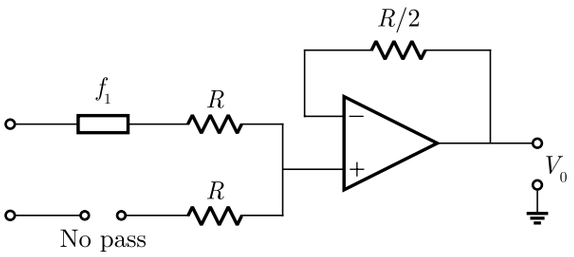
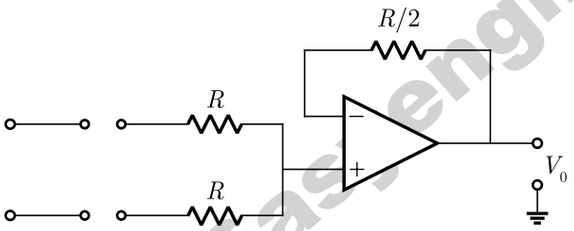
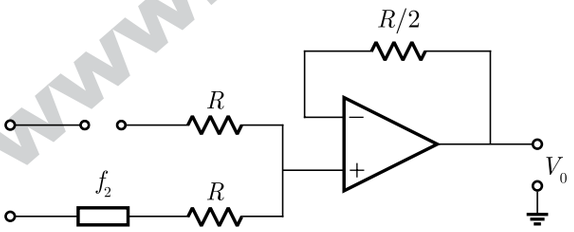


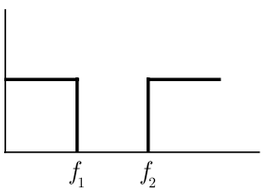
Again, for $f_1 < f < f_2$, the op-amp circuit is



For $f > f_2$, the op-amp circuit is

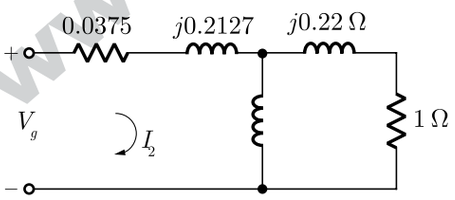


Hence, the output graph is



Thus, the resultant circuit represents a band stop filter.

Q. 20 The figure shows the per-phase equivalent circuit of a two-pole three-phase induction motor operating at 50 Hz. The "air-gap" voltage, V_g across the magnetizing inductance, is 210 V rms, and the slip, is 0.005. The torque (in Nm) produced by the motor is_____



Sol. 20 Correct answer is 401.69

We redraw the given circuit as

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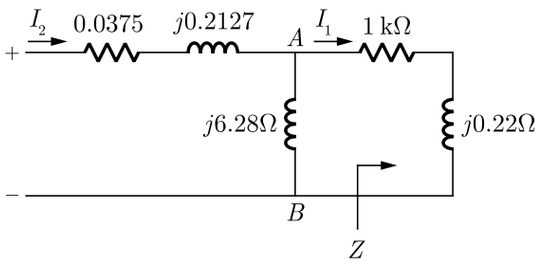


Given $V_g = 210$ V

$s = 0.005$

Air gap voltage is the voltage across AB, i.e.

$$V_{AB} = V_g = 210 \text{ V (rms)}$$

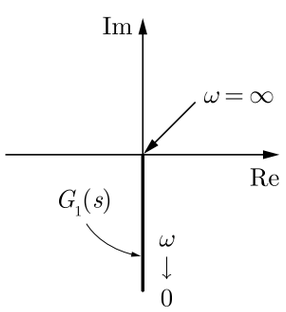
So, $$I_2 = \frac{V_{AB}}{Z}$$

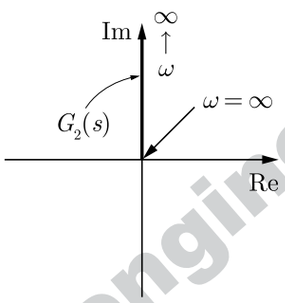
$$= \frac{V_{AB}}{Z} = \frac{210}{1 + j0.22} = 205.0953\angle -12.40$$

Hence, $$\text{torque} = \frac{3}{W_s} I_2^2 \frac{r_2^2}{s}$$

$$= \frac{3}{314.15}(205.0953)^2 \times 1 = 401.69 \text{ N-m}$$

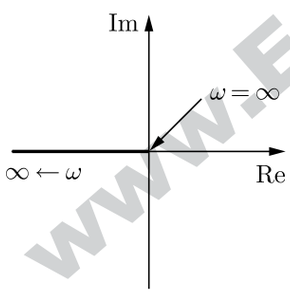
Q. 21 Nyquist plots of two functions $G_1(s)$ and $G_2(s)$ are shown in figure.



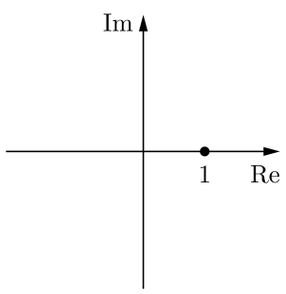


Nyquist plot of the product of $G_1(s)$ and $G_2(s)$ is

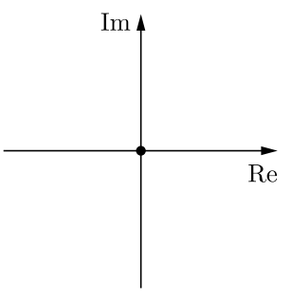
(A)



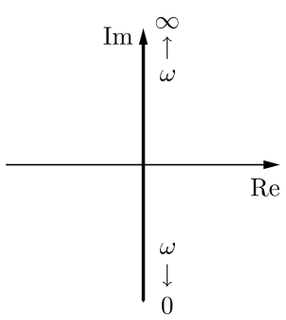
(B)



(C)



(D)



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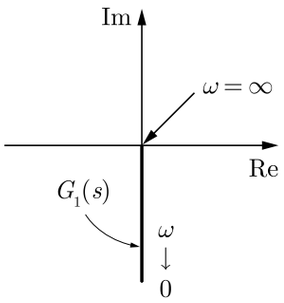
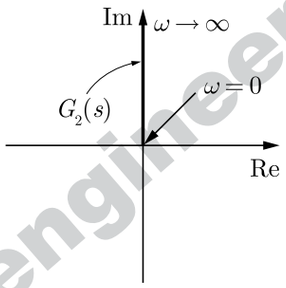
Sol. 21 Correct option is (B).

Given Nyquist plot of the two functions $G_1(s)$ and $G_2(s)$,

Function G_1



Function G_2



From the Nyquist plot, we have

$$F_{G1}(s) = \frac{K_1}{s}$$

$$F_{G2}(s) = K_2 s$$

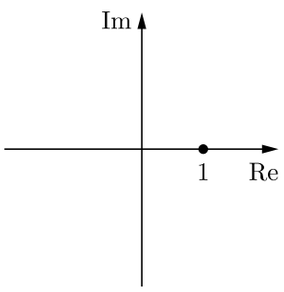
So, the product of F_1 and F_2 is obtained as

$$F(s) = F_{G1}(s)F_{G2}(s)$$

$$= \frac{K_1}{s} K_2 s$$

$$= K_1 K_2$$

This value is constant, hence resulting Nyquist plot is (Here $K_1K_2 = 1$).



Q. 22 A 3-phase balanced load which has a power factor of 0.707 is connected to balanced supply. The power consumed by the load is 5 kW. The power is measured by the two-wattmeters method. The readings of the two wattmeters are

(A) 3.94 kW and 1.06 kW (B) 2.50 kW and 2.50 kW

(C) 5.00 kW and 0.00 kW (D) 2.96 kW and 2.04 kW

Sol. 22 Correct option is (A).

Given p.f. $= 0.707$

Power consumed by the load is

$$W_1 + W_2 = 5\,\text{kW}$$

By two wattmeter method experiment, we have

$$\phi = \tan^{-1}\left(\sqrt{3}\left(\frac{W_1 - W_2}{W_1 + W_2}\right)\right)$$

or $$45^\circ = \tan^{-1}\left(\sqrt{3}\left(\frac{W_1 - W_2}{5}\right)\right)$$

or $$\tan 45^\circ = \sqrt{3}\left(\frac{W_1 - W_2}{5}\right)$$

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or $\frac{1}{\sqrt{3}} \times 5 = W_1 - W_2$

or $W_1 - W_2 = \frac{5}{\sqrt{3}}$

From equations (1) and (2), we obtain

$$2W_1 = 5 + \frac{5}{\sqrt{3}}$$

So, $W_1 = \frac{5 + \frac{5}{\sqrt{3}}}{2} = 3.94\,\text{kW}$

and $W_2 = \frac{5 - \frac{5}{\sqrt{3}}}{2}\ W_2 = 1.06\,\text{kW}$

Q. 23 An open loop control system results in a response of $e^{-2t}(\sin 5t + \cos 5t)$ for a unit impulse input. The DC gain of the control system is _____

Sol. 23 Correct answer is 0.241

Given $g(t) = e^{-2t}(\sin 5t + \cos 5t)$

For a unit impulse input, output response is

$$G(s) = L(e^{-2t}\sin 5t + e^{-2t}\cos 5t)$$
$$= \frac{5}{(s+2)^2 + 5^2} + \frac{5+2}{(s+2)^2 + 5^2}$$

Hence, the dc gain is obtained as

$$G(s)\big|_{s=0} = \frac{5}{2^2 + 5^2} + \frac{2}{2^2 + 5^2}$$
$$= \frac{7}{2^2 + 5^2}$$
$$= 0.241$$

Q. 24 When a bipolar junction transistor is operating in the saturation mode, which one of the following statement is TRUE about the state of its collector-base (CB) and the base-emitter (BE) junctions ?

(A) The CB junction is forward biased and the BE junction is reverse biased.

(B) The CB junction is reversed and the BE junction is forward biased.

(C) Both the CB and BE junctions are forward biased.

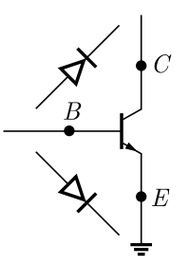
(D) Both the CB and BE junctions are reverse

Sol. 24 Correct option is (C).

In Bipolar transistor, saturation mode occurs when

1. Collector-base (CB) is forward biased.
2. Base-Emitter (BE) is also forward biased.

Hence, for the saturation condition, both the junction should be in forward bias, as shown in figure below.



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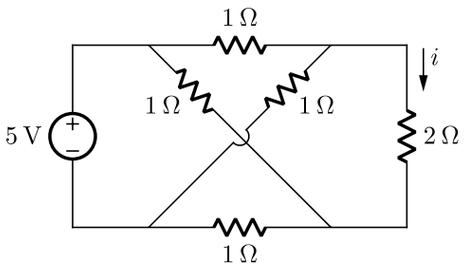
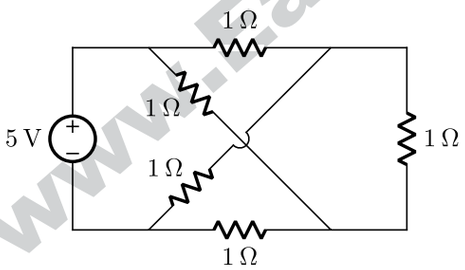
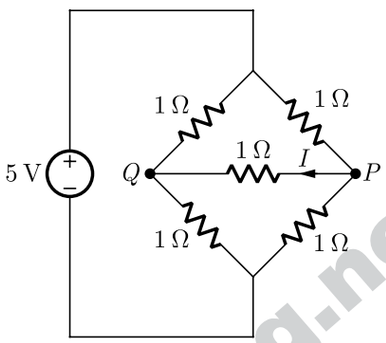
Q. 25 The current i (in Ampere) in the $2\,\Omega$ resistor of the given network is _____



Sol. 25 Correct answer is 0.

We redraw the given circuit as





Here, it is balanced wheatstone bridge. No current will flow through PQ branch because they are at same potential.

Q. 26 - Q. 55 Carry two marks each.

Q. 26 A 220 V, 3-phase, 4-pole, 50 Hz inductor motor of wound rotor type is supplied at rated voltage and frequency. The stator resistance, magnetizing reactance, and core loss are negligible. The maximum torque produced by the rotor is 225% of full load torque and it occurs at 15% slip. The actual rotor resistance is $0.03\,\Omega$ /phase. The value of external resistance (in Ohm) which must be inserted in a rotor phase If the maximum torque is to occur at start is _____

Sol. 26 Correct answer is 0.17

Given wound rotor induction motor with

220 V, 3-phase, 4-pole, 50 Hz

Maximum torque is produced at 15% slip. So, we have

$$s_m = \frac{r_2}{x_2}$$

$$0.15 = \frac{r_2}{x_2}$$

$$0.15 = \frac{0.03}{x_2}$$

$$x_2 = 0.2\,\Omega$$

Now, it is required to have maximum torque at starting, i.e.

$$T_{\text{st}} = T_{\max}$$

Since, $$\frac{T_{st}}{T_m} = \frac{2s_m}{s_m^2 + 1}$$

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So, $s_m^2 + 1 = 2s_m$ $(T_{st}/T_m = 1)$

$(s_m - 1)^2 = 0$

$s_m = 1$

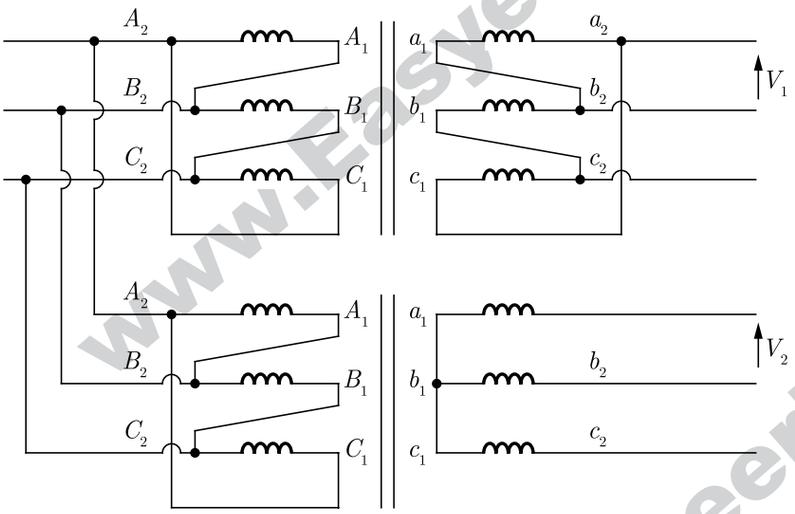
or $\frac{r_2'}{x_2} = 1$

Hence, $r_2' = x_2 = 0.2\,\Omega$

Thus, the value of external resistance, to be added, is

$$r_2' - r_2 = 0.2 - 0.03 = 0.17\,\Omega$$

Q. 27 Two three-phase transformers are realized using single-phase transformers as shown in the figure.

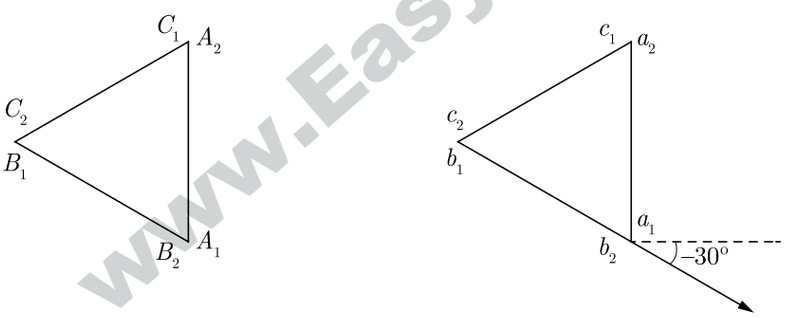


The phase difference (in degree) between voltage V_1 and V_2 is_____

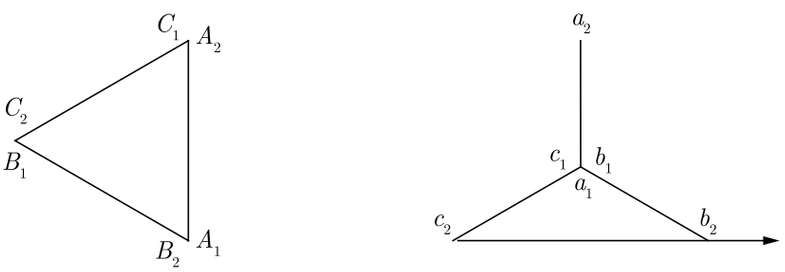
Sol. 27 Correct answer is 30.

Two three-phase transformers are realized using single-phase transformers. Single phase transformers are connected as shown in figures below.

First transformer is in Δ-Δ.



Second transformer is in Δ-Y.



In both the case, if we join the two point $c_2 b_2$ then, we can observe that the phase difference is equal to 30° in Δ-Δ and Δ-Y.

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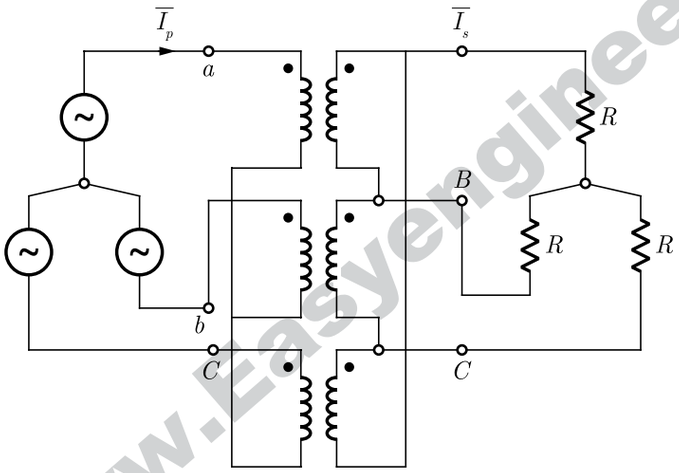
Q. 28 A balanced (positive sequence) three- phase AC voltage source is connected to a balanced, start connected through a star-delta transformer as shown in the figure. The line-to-line voltage rating is 230 V on the star side, and 115 V on the delta side. If the magnetizing current is neglected and $\overline{I}_s = 100\angle 0^\circ\, A$, then what is the value of $\overline{I}_p$ in Ampere?



(A) $50\angle 30^\circ$ (B) $50\angle -30^\circ$

(C) $50\sqrt{3}\angle 30^\circ$ (D) $200\angle 30^\circ$

Sol. 28 Correct option is (A).

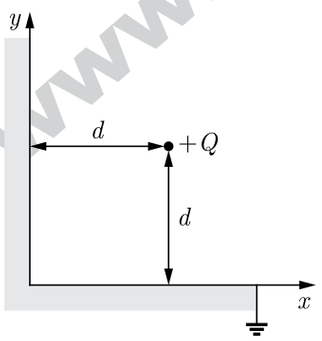
Voltage difference between star and delta is 30°. In secondary side, there is delta connection, so current in each phase will be $I_L/\sqrt{3}$. In primary side, there is star connection, so voltage in each phase will be $V_L/\sqrt{3}$. Since, KVA is constant for both phase, so we may write

$$(\text{kVA})_{1(\text{per phase})} = (\text{kVA})_{2(\text{per phase})}$$

$$\left(\frac{230}{\sqrt{3}}\angle 0^\circ\right)(I_p) = (115\angle 30^\circ)\left(\frac{100}{\sqrt{3}}\right)$$

Hence, $I_p = 50\angle 30^\circ$

Q. 29 Two semi-infinite conducting sheets are placed at right angles to each other as shown in the figure. A point charge of $+Q$ is placed at a distance of d from both sheets. The net force on the charge is $\frac{Q^2}{4\pi\varepsilon_0}\frac{K}{d^2}$, where K is given by



(A) 0 (B) $-\frac{1}{4}\hat{i} - \frac{1}{4}\hat{j}$

(C) $-\frac{1}{8}\hat{i} - \frac{1}{8}\hat{j}$ (D) $\frac{1-2\sqrt{2}}{8\sqrt{2}}\hat{i} + \frac{1-2\sqrt{2}}{8\sqrt{2}}\hat{j}$

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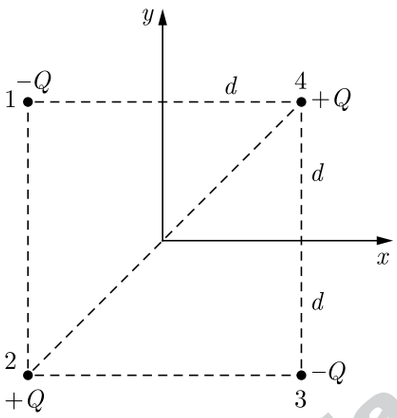
Sol. 29 Correct option is (D).

Here, we obtain the net force using image charge method. The equivalent image charge diagram for the given system is shown below.



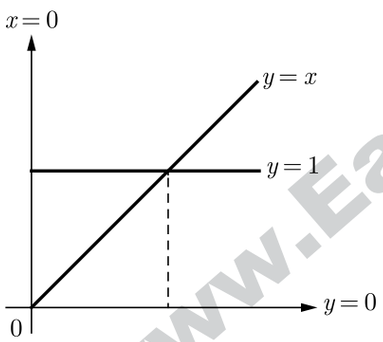
So, net force on A is obtained as

$$\begin{aligned} F_{net} &= F_1 + F_2 + F_3 \\ &= \frac{Q^2}{4\pi\varepsilon_0(2d)^2}(-2d\hat{a}_x) + \frac{Q^2}{4\pi\varepsilon_0(2d)^2} \times \left(\frac{2d}{2\sqrt{2}}\hat{a}_x + \frac{2}{2\sqrt{2}}\hat{a}_y\right) \\ &\qquad + \frac{Q^2}{4\pi\varepsilon_0(2d)^2}(-2d\hat{a}_y) \\ &= \frac{Q^2}{4\pi\varepsilon_0 d^2}\left[\frac{1-2\sqrt{2}}{8\sqrt{2}}\hat{a}_x + \frac{1-2\sqrt{2}}{8\sqrt{2}}\hat{a}_y\right] \end{aligned}$$

Q. 30 The volume enclosed by the surface $f(x, y) = e^x$ over the triangle bounded by the line $x = y; x = 0; y = 1$ in the xy plane is_____

Sol. 30 Correct answer is 0.71

The given equation of line is drawn in the co-ordinate system.



So, required area between $x = 0$, $y = 0$, $x = y$ and $y = 1$ is

$$\begin{aligned} A &= \int_{x=0}^{x=1}\int_{y=x}^{y=1} f(x,y)\,dxdy \\ &= \int_{x=0}^{x=1}\int_{y=x}^{y=1} e^x\,dxdy \end{aligned}$$

By changing the order of integration,

$$\begin{aligned} A &= \int_{y=0}^{y=1}\int_{x=0}^{x=y} e^x\,dxdy \\ &= \int_{y=0}^{y=1}\left[e^x\right]_0^y\,dy \\ &= \int_{y=0}^{y=1}(e^y - 1)\,dy \end{aligned}$$

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$$= [e^y - y]_0^1$$
$$= (e^1 - 1) - (e^0 - 0)$$
$$= 2.71 - 2 = 0.71$$

Q. 31 For the system governed by the set of equations:

$$\frac{dx_1}{dt} = 2x_1 + x_2 + u$$
$$\frac{dx_2}{dt} = -2x_1 + u$$
$$y = 3x_1$$

The transfer function $\frac{Y(s)}{U(s)}$ is given by

(A) $\frac{3(s+1)}{(s^2-2s+2)}$ (B) $3(2s+1)(s^2-2s+1)$

(C) $\frac{(s+1)}{(s^2-2s+1)}$ (D) $3(2s+1)(s^2-2s+2)$

Sol. 31 Correct option is (A).

Given equations of the system

$$\dot{x}_1 = 2x_1 + x_2 + U$$
$$\dot{x}_2 = -2x_1 + U$$
$$y = 3x_1$$

In matrix form, we may write the equation as

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\end{bmatrix} = \begin{bmatrix}2 & 1\\ -2 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} + \begin{bmatrix}1\\ 1\end{bmatrix}U$$
$$Y = \begin{bmatrix}3 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix}$$

So, we have

$$A = \begin{bmatrix}2 & 1\\ -2 & 0\end{bmatrix}$$
$$B = \begin{bmatrix}1\\ 1\end{bmatrix}$$
$$C = \begin{bmatrix}3 & 0\end{bmatrix}$$

Transfer function is obtained using the formula,

$$\text{T.F.} = C(sI - A)^{-1}B$$

Since, we have

$$sI - A = \begin{bmatrix}s-2 & -1\\ 2 & s\end{bmatrix}$$

Hence, we obtain

$$\text{T.F.} = C(sI - A)^{-1}B$$
$$= \begin{bmatrix}3 & 0\end{bmatrix}\begin{bmatrix}s-2 & -1\\ 2 & s\end{bmatrix}^{-1}\begin{bmatrix}1\\ 1\end{bmatrix}$$
$$= \frac{1}{s(s-2)+2}\begin{bmatrix}3 & 0\end{bmatrix}\begin{bmatrix}s & 1\\ -2 & s-2\end{bmatrix}\begin{bmatrix}1\\ 1\end{bmatrix}$$
$$= \frac{1}{s^2-2s+2}\begin{bmatrix}3 & 0\end{bmatrix}\begin{bmatrix}s+1\\ s-4\end{bmatrix}$$
$$= \frac{3(s+1)}{s^2-2s+2}$$

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Q. 32 For linear time invariant systems, that are Bounded Input Bounded stable, which one of the following statement is TRUE?

(A) The impulse response will be integral, but may not be absolutely integrable.

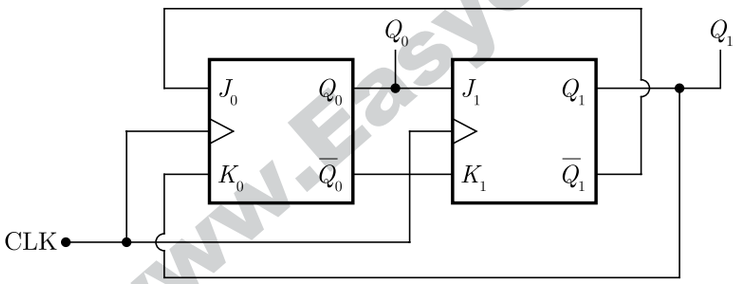
(B) The unit impulse response will have finite support

(C) The unit step response will be absolutely integrable.

(D) The unit step response will be bounded.

Sol. 32 Correct option is (D).

Q. 33 In the following sequential circuit, the initial state (before the first clock pulse) of the circuit is $Q_1 Q_0 = 00$. The state $(Q_1 Q_0)$, immediately after the 333^{rd} clock pulse is



(A) 00 (B) 01

(C) 10 (D) 11

Sol. 33 Correct option is (B).

For the given sequential circuit, initial state is

$$(Q_1 Q_2) = 0\,0$$

Given circuit represents Johnson er, so we have the truth table as

$J_1(Q_0)$	$K_1(\overline{Q}_0)$	$J_0(\overline{Q}_1)$	$K_0(Q_1)$	Q_1	Q_0
				0	0
0	1	1	0	0	1
1	0	1	0	1	1
1	0	0	1	1	0
0	1	0	1	0	0

From above table, we can observe that the given circuit is a Johnson (mod-4) er for which the output sequence is

Q_1	Q_0
0	0
0	1
1	1
1	0

Hence, after 332 clock pulse, we have

$$(Q_1, Q_0) = (0,0)$$

Thus, in the next cycle, i.e. after 333 clock pulse, we get

$$(Q_1, Q_0) = (0,1)$$

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Q. 34 A three-phase, 11 kV, 50 Hz, 2 pole, star connected, cylindrical rotor synchronous motor is connected to an 11 kV, 50 Hz source. Its synchronous reactance is 50 Ω per phase, and its stator resistance is negligible. The motor has a constant field excitation. At a particular load torque, its stator current is 100 A at unity power factor. If the load torque is increased so that the stator current is 120 A, then the load angle (in degrees) at this node is_____

Sol. 34 Correct answer is –48 to –46.

Q. 35 Two coins R and S are tossed. The 4 joint events $H_R H_S, T_R T_S, H_R T_s, T_R H_S$ have probabilities 0.28, 0.18, 0.30, 0.24, respectively, where H represents head and T represents tail. Which one of the following is TRUE ?

(A) The coin tosses are independent.

(B) R is fair, S is not.

(C) S is fair, R is not.

(D) The coin tosses are dependent.

Sol. 35 Correct option is (D).

Two coins R and S are tossed, so there are 4 joint events given as

$$P(H_R H_S) = 0.28$$
$$P(T_R T_S) = 0.18$$
$$P(H_R T_S) = 0.30$$
$$P(T_R H_S) = 0.24$$

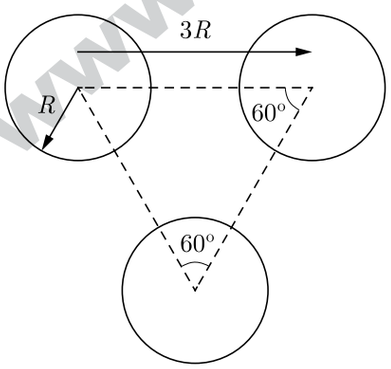
Now, we consider the statement given in option (A). If coin tosses are independent, then

$$P(H_R H_S) = P(H_R)P(H_S)$$
$$= \frac{1}{2} \times \frac{1}{2}$$
$$= \frac{1}{4}$$

But, given value is 0.28, so these coin tosses are not independent.

Hence, coin tosses are dependent, which is stated in option (D).

Q. 36 A composite conductor consists of three conductors of radius R each. The conductors are arranged as shown below. The geometric mean radius (GMR) (in cm) of the composite conductor is kR. The value of k is_____



Sol. 36 Correct answer is 1.913

We have to obtain the GMR of composite conductor. Given conductor arrangement is redrawn below.

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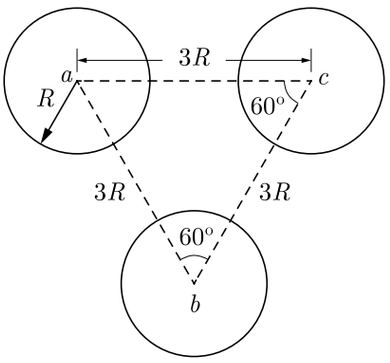

From the figure, we have

$$\text{GMR} = 3\sqrt{r_a \times r_{ab} \times r_{ac}}$$
$$= \sqrt{r' \times r_{ab} \times r_{ac}}$$
$$= \sqrt{7788 \times R \times 3R \times 3R}$$
$$\text{GMR} = 1.913R$$

Hence, $k = 1.913$

Q. 37 The z-Transform of a sequence $x[n]$ is given as

$$X(z) = \frac{2z+4-4}{\frac{z+3}{z^2}}$$

If $y[n]$ is the first difference of $x[n]$, then $Y(z)$ is given by

(A) $2z+2-8/z+7/z^2-3/z^3$ (B) $-2z+2-6/z+1/z^2-3/z^3$

(C) $-2z-2+8/z-7/z^2+3/z^3$ (D) $4z-2-8/z-1/z^2+3/z^3$

Sol. 37 Correct option is (A).

Given z-transform of sequence $x[n]$ as

$$X(z) = 2z+4-\frac{4}{z}+\frac{3}{z^2}$$

$y[n]$ is the first difference of $x[n]$, i.e.

$$y[n] = x[n]-x[n-1]$$

Taking its z-transform, we get

$$Y(z) = X(z)-z^{-1}X(z)$$
$$= (1-z^{-1})X(z)$$
$$= (1-z^{-1})\left(2z+4-\frac{4}{z}+\frac{3}{z^2}\right)$$
$$= 2z+4-\frac{4}{z}+\frac{3}{z^2}-2-\frac{4}{z}+\frac{4}{z^2}-\frac{3}{2^3}$$

Hence, $Y(z) = 2z+2-8z^{-1}+7z^{-2}-3z^{-3}$

Q. 38 An open loop transfer function

$$G(s) = \frac{K}{s(s+1)(s+2)}$$

For a unity feedback system, the breakaway point of the root loci on the real axis occurs at,

(A) -0.42

(B) -1.58

(C) -0.42 and 1.58

(D) None of the above

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Sol. 38 Correct option is (A).

Given open loop transfer function,

$$G(s) = \frac{K}{s(s+1)(s+2)}$$

So, the characteristic equation is obtained as

$$1 + G(s)H(s) = 0$$

$$1 + \frac{K}{s(s+1)(s+2)} = 0$$

Expressing the equation in terms of K, we have

$$\begin{aligned} K &= -(s)(s+1)(s+2) \\ &= -s(s^2+3s+2) \\ &= -s^3 - 3s^2 - 2s \end{aligned}$$

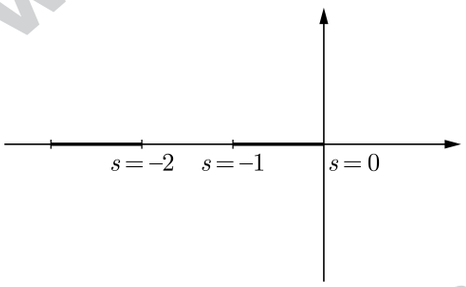
To check the existence of point on root locus, we solve the equation

$$\frac{dK}{ds} = 0$$

or $$\frac{dK}{ds} = -3s^2 - 6s - 2 = 0$$

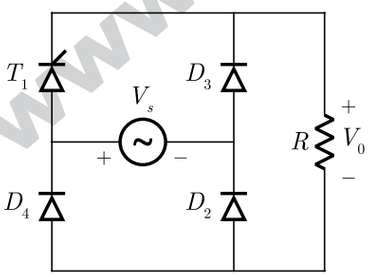
or $$s = -0.42, -1.58$$

Now, we have the root locus for the given system as shown below.



From the root loci, we can observe that -0.42 lie in the region in which root locus exist, so -0.42 is a breakaway point. But -1.58 exists between $(-2,-1)$, and does not lie on the root locus, hence it is not a breakaway point.

Q. 39 In the given rectifier, the delay angle of the thyristor T_1 measured from the positive going zero crossing of V_s is 30°. If the input voltage V_s is $100\sin(100\pi t)\,V$, the average voltage across R (in Volt) under steady-state is_____



Sol. 39 Correct answer is 61.52

Given rectifier circuit,

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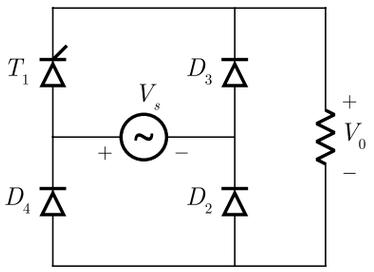
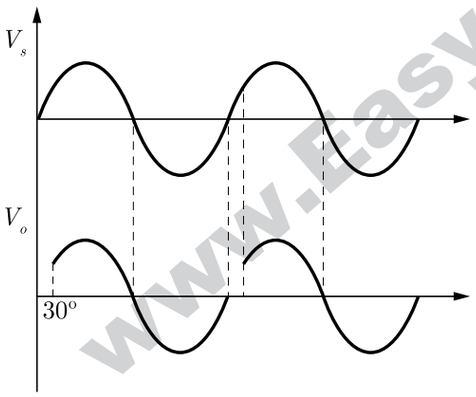


The applied source voltage is

$$V_s = 100\sin(100\pi t)$$

The source voltage and output voltage is illustrated in the figure below.



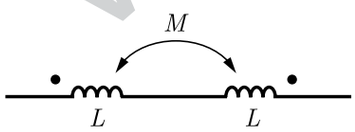
From the shown waveform, we obtain the average output voltage in steady state as

$$\begin{aligned} V_o &= \frac{1}{2\pi}\int_{\alpha}^{2\pi}\sin(100\pi t)\,d(\omega t) \\ &= \frac{100}{2\pi}[3+\cos\alpha] \\ &= \frac{100}{2\pi}(3+\cos 30^\circ) \\ &= 61.52\ \text{V} \end{aligned}$$

Q. 40 Two identical coils each having inductance L are placed together on the same core. If an overall inductance of αL is obtained by interconnecting these two coils, the minimum value of α is_____

Sol. 40 Correct answer is 0.

Here, we consider the mutual inductance for two identical coils connected in series, as shown below.



Coefficient of coupling is given by

$$K \le \frac{M}{\sqrt{L_1 L_2}}$$

$$M \ge K\sqrt{L_1 L_2}$$

Here, we have

$$L_1 = L_2$$

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So, we get

$$M \geq KL$$

Therefore, the equivalent inductance is given by

$$L_{eq} = L_1 + L_2 - 2M \qquad \text{(when polarity is different)}$$
$$= 2L - 2M$$
$$= 2L - 2KL$$

For minimum value of L_{eq}, we use maximum value of K, i.e. $K = 1$. Hence, we get

$$L_{eq} = 2L - 2L = 0$$

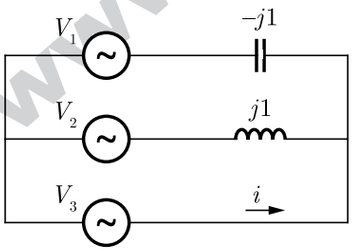
Given $L_{eq} = \alpha L$

So, the minimum value of α is 0.

Q. 41 In the given network

$$V_1 = 100\angle 0^\circ \text{ V}$$
$$V_2 = 100\angle -120^\circ \text{ V}$$
$$V_3 = 100\angle +120^\circ \text{ V}$$

The phasor current i (in Ampere) is

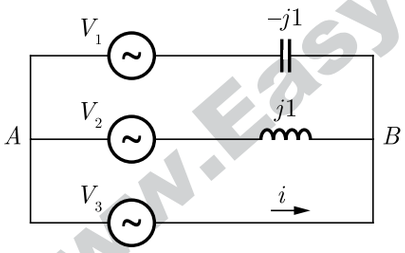


(A) $173.2\angle 60^\circ$ (B) $173.2\angle -120^\circ$

(C) $100.0\angle -60^\circ$ (D) $100.0\angle -120^\circ$

Sol. 41 Correct option is (A).

Given network is redrawn as



We apply the nodal analysis to solve the problem.

Let Voltage at node $B = 0$ (reference voltage)

So, Voltage at node $A = V_3$

Applying KCL, we have

$$\frac{V_3 - V_1}{-j1} + \frac{V_3 - V_2}{j1} + i = 0$$

$$i = -\frac{V_3 - V_1}{-j1} - \frac{V_3 - V_2}{j1}$$
$$= \frac{1}{j1}[+V_3 - V_1 - V_3 + V_2]$$
$$= \frac{1}{j1}[V_2 - V_1]$$

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$$= \frac{1}{j1}[100\angle -120^\circ - 100\angle 0^\circ]$$

Hence, $i = 173.2\angle 60^\circ$

Q. 42 A differential equation $\frac{di}{dt} - 0.2i = 0$ is applicable over $-10 < t < 10$. If $i(4) = 10$, then $i(-5)$ is_____

Sol. 42 Correct answer is 1.65

Given differential equation,

$$\frac{di}{dt} - \frac{1}{5}i = 0 \quad \text{for } -10 < t < 10$$

Solving the differential equation, we obtain

$$\frac{di}{i} = \frac{1}{5}dt$$

$$\ln i = \frac{1}{5}t + C$$

$$i = e^{\frac{1}{5}t} + C$$

$$i = e^C e^{\frac{1}{5}t}$$

$$i = Ae^{\frac{1}{5}t}$$

Now, we have

$$i(4) = 10$$

Substituting it in equation (1), we get

$$10 = Ae^{\frac{4}{5}}$$

or $$A = \frac{10}{e^{4/5}}$$

Then, value of i at $t = -5$ sec is

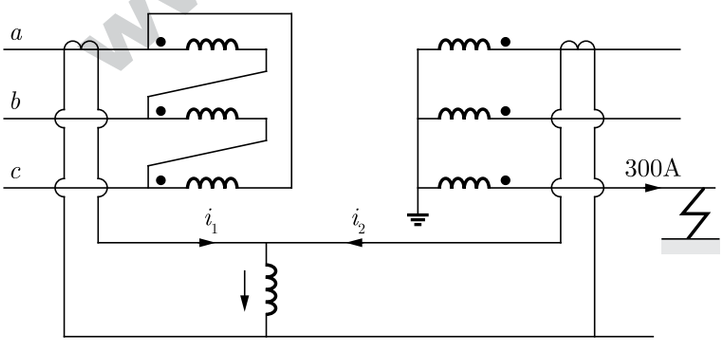
$$i(-5) = Ae^{\frac{1}{5}(-5)}$$

$$= \frac{10}{e^{4/5}}e^{-1}$$

$$= 10e^{-1-\frac{4}{5}}$$

$$= 10e^{-9/5} = 1.65$$

Q. 43 A 3-phase transformers rated for 33 kV/11 kV is connected in delta/star as shown in figure. The current transformer (CTs) on low and high voltage sides have a ratio of 500/5. Find the currents i_1 and i_2, if the fault current is 300 A as shown in figure.



(A) $i_1 = 1/\sqrt{3}\,A, i_2 = 0\,A$

(B) $i_1 = 0A, i_2 = 1A$

(C) $i_1 = 0A, i_2 = 1/\sqrt{3}A$

(D) $i_1 = 1/\sqrt{3}\,A, i_2 = 1/\sqrt{3A}$

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Sol. 43 Correct option is (A).

Given that 3-phase transformer 33/11 kV is connected in delta-star connection. Since, fault is in star connected side, so all the current flow through fault and no current will pass through circuit of secondary side, i.e.

$$i_2 = 0$$

By using transformer equation, we have

$$\text{Primary kVA} = \text{Secondary kVA}$$

or $$\sqrt{3} \times V_L I_L = \sqrt{3}\, V_L I_L$$

or $$\sqrt{3} \times 33000 \times I_L = \sqrt{3} \times 11000 \times \left(300 \times \frac{5}{500}\right)$$

So, $$I_L = 1 \text{ A}$$

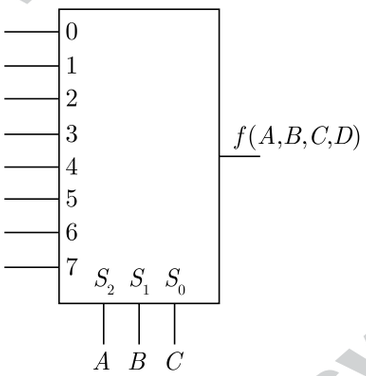
Since, primary side is delta connected. So, we have

$$I_L = \sqrt{3}\, I_{ph}$$

or $$\sqrt{3}\, I_{ph} = 1$$

Hence, $$I_{ph} = \frac{1}{\sqrt{3}} \text{ A}$$

Q. 44 A Boolean function $f(A,B,C,D) = \Pi(1,5,12,15)$ is to be implemented using an 8×1 multiplexer (A is MSB). The inputs ABC are connected to the select inputs $S_2S_1S_0$ of the multiplexer respectively.



Which one of the following options gives the correct input to pins 0,1,2,3,4,5,6,7 in order ?

(A) $D,0,D,0,0,0,\overline{D},D$

(B) $\overline{D},1,\overline{D},1,1,1,D,\overline{D}$

(C) $D,1,D,1,1,1,\overline{D},D$

(D) $\overline{D},0,\overline{D},0,0,0,D,\overline{D}$

Sol. 44 Correct option is (B).

Given Boolean function,

$$f(A,B,C,D) = \pi(1,5,12,15)$$

In form of sum of minterms, we have

$$f(A,B,C,D) = (0,2,3,4,6,7,8,9,10,11,13,14)$$

So, we obtain the input to pins as

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	I_0	I_1	I_2	I_3	I_4	I_5	I_6	I_7
$\overline{D}$	⓪	②	④	⑥	⑧	⑩	12	⑭
D	1	③	5	⑦	⑨	⑪	⑬	15
	$\overline{D}$	1	$\overline{D}$	1	1	1	D	$\overline{D}$

Hence, the correct input to pins 0,1,2,3,4,5,6,7 in order are $\overline{D}, 1, \overline{D}, 1, 1, 1, D, \overline{D}$

Q. 45 The incremental costs (in Rupees/MWh) of operating two generating units are functions of their respective powers P_1 and P_2 in MW, and are given by

$$\frac{dC}{dP_1} = 0.2P_1 + 50$$

$$\frac{dC}{dP_2} = 0.24P_2 + 40$$

where

$$20 \text{ MW} \le P_1 \le 150 \text{ MW}$$

$$20 \text{ MW} \le P_2 \le 150 \text{ MW}$$

For a certain load demand, P_1 and P_2 have been chosen such that $dC_1/dP_1 = 76$ Rs/MWh and $dC_2/dP_2 = 68.8$ Rs/MWh. If the generations are rescheduled to minimize the total cost, that P_2 is_____

Sol. 45 Correct answer is 136.36

Initially P_1 and P_2 are chosen in such a way that

$$\frac{dC_1}{dP_1} = 76 \text{ Rs/MWh}$$

$$\frac{dC_2}{dP_2} = 68.8 \text{ Rs/MWh}$$

Now, we calculate values of P_1 and P_2 as

$$0.2P_1 + 50 = 76$$

$$P_1 = 130 \text{ MW}$$

$$0.24P_2 + 40 = 68.8$$

$$P_2 = 120 \text{ MW}$$

So, Total demand $= 120 + 130 = 250$ MW

If generation cost is rescheduled to minimize the total cost, then incremental production cost should be equal, i.e.

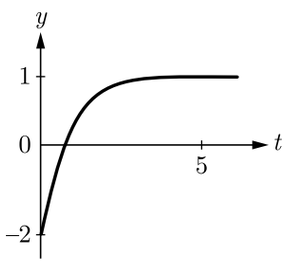
$$0.2P_1 + 50 = 0.24P_2 + 40$$

$$0.2(250 - P_2) + 50 = 0.24P_2 + 40$$

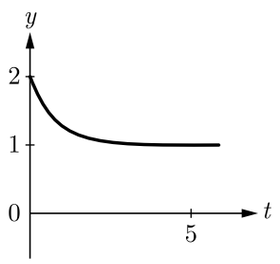
$$P_2 = 136.36 \text{ MW}$$

Q. 46 The unit step response of a system with the transfer function $G(s) = \dfrac{1-2s}{1+s}$ is given by which one of the following waveforms ?

(A)



(B)



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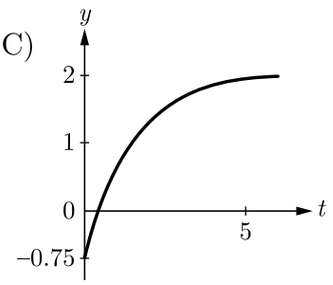
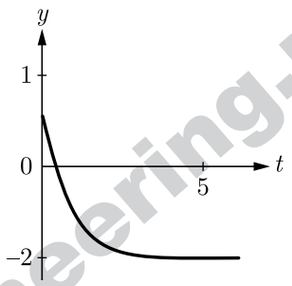
(C)



(D)



Sol. 46 Correct option is (A).

Given transfer function,

$$G(s) = \frac{1-2s}{1+s}$$

Output of the system is given by

$$C(s) = G(s)R(s)$$

When system is excited by unit step input, the output is

$$C(s) = \left(\frac{1-2s}{1+s}\right)\left(\frac{1}{s}\right)$$

Let $$C(s) = \frac{A}{s} + \frac{B}{1+s}$$

So, we obtain

$$A = \lim_{s\to 0}\frac{1-2s}{1+s} = 1$$

$$B = \lim_{s\to -1}\frac{1-2s}{s} = -3$$

Hence, $$C(s) = \frac{1}{s} - \frac{3}{s+1}$$

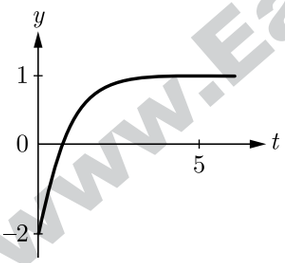
Taking inverse Laplace transform,

$$C(t) = (1-3e^{-t})4(t)$$

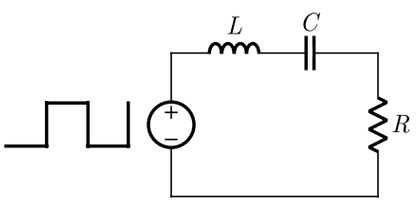
At $t = 0$, $$C(0) = (1-3e^{0})1 = -2$$

At $t = \infty$, $$C(\infty) = (1-3e^{-\infty})1 = (1-0) = 1$$

Hence, the time domain waveform for output is obtained as



Q. 47 A symmetrical square wave of 50% duty cycle has amplitude of ± 15 V and time period of 0.4π ms. This square wave is applied across a series RLC circuit with $R = 5\,\Omega$, $L = 10$ mH, and $C = 4\,\mu$F. The amplitude of the 5000 rad/s component of the capacitor voltage (in Volt) is_____



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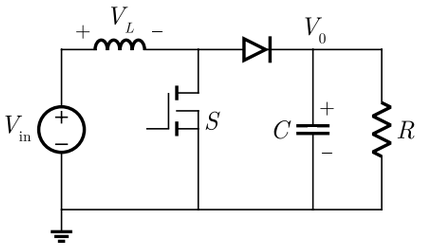
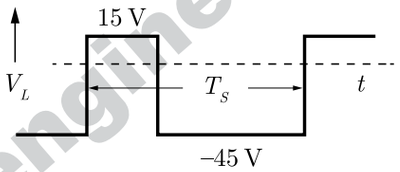
Sol. 47 Correct answer is 190 to 192.

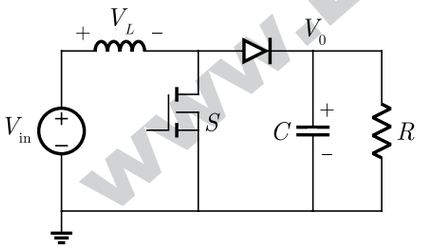
Q. 48 For the switching converter shown in the following figure, assume steady-state operation. Also assume that the components are ideal, the inductor current is always positive and continuous and switching period is T_5. If the voltage V_L is as shown, the duty cycle of the switch S is_____

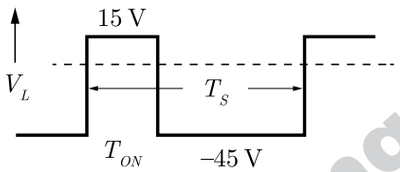




Sol. 48 Correct answer is 0.75

We have the switching converter as





When switch is ON, we have

$$V_L = V_{in} = 15\ \text{V}$$

When switch is OFF, then

$$V_L = V_{in} - V_o$$

or $$-45 = 15 - V_o$$

or $$V_o = 60\ \text{V}$$

So, this is a step-up chopper, and therefore we have

$$V_o = \frac{V_s}{1-\alpha}$$

or $$60 = \frac{15}{1-\alpha}$$

Hence, $$\alpha = 0.75$$

Q. 49 With an armature voltage of 100 V and rated field winding voltage, the speed of a separately excited DC motor driving a fan is 1000 rpm, and its armature current is 10 A. The armature resistance is 1 Ω. The load torque of the fan load is proportional to the square of the rotor speed. Neglecting rotational losses, the value of the armature voltage (in Volt) which will reduce the rotor speed to 500 rpm is_____

Sol. 49 Correct answer is 47.5

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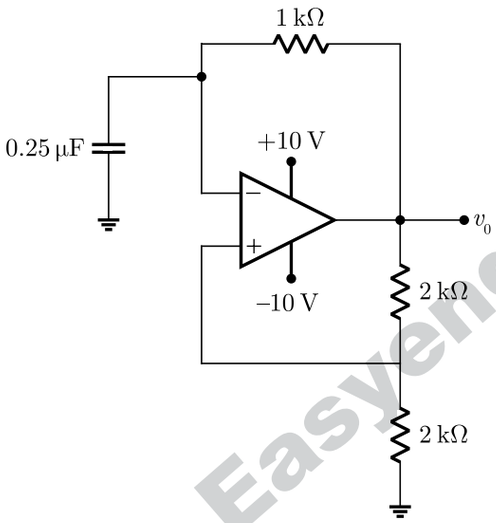
Q. 50 The saturation voltage of the ideal op-amp shown below is ± 10 V. The output voltage v_0 of the following circuit in the steady-state is



(A) Square wave of period 0.55 ms

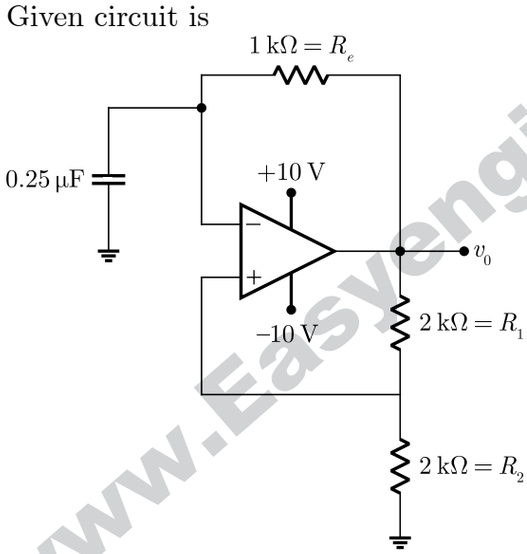
(B) Triangular wave of period 0.55 ms

(C) Square wave of period 0.25 ms

(D) Triangular wave of period 0.25 ms

Sol. 50 Correct option is (A).

Given circuit is



This is astable multivibrator, so it gives square waveform. Time period of the square waveform is given by

$$T = 2RC\ln\left(\frac{1+\beta}{1-\beta}\right)$$

where $$\beta = \frac{R_2}{R_1+R_2} = \frac{2}{2+2} = 0.5$$

So, $$T = 2R_eC\ln\left(\frac{1+0.5}{1-0.5}\right)$$

$$= 2\times 1\times 10^3 \ln\left(\frac{1.5}{.5}\right)\times .25\times 10^{-6}$$

$$= 2\times 10^{-3}\ln(3)\times .25\times 10^{-6}$$

Hence, $$T = 0.55 \text{ msec}$$

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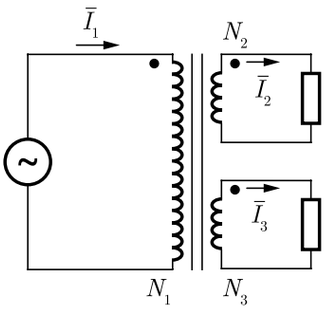
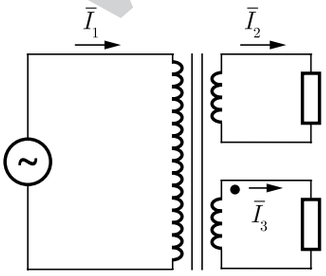
Q. 51 A three-winding transformer is connected to an AC voltage source as shown in the figure. The number of turns are as follows: $N_1 = 100$, $N_2 = 50$. If the magnetizing current is neglected, and the currents in two windings are $\bar{I}_2 = 2\angle 30^\circ$ A and $\bar{I}_3 = 2\angle 150^\circ$ A, then what is the value of the current $\bar{I}_1$ in Ampere?



(A) $1\angle 90^\circ$
(B) $1\angle 270^\circ$
(C) $4\angle 90^\circ$
(D) $4\angle 270^\circ$

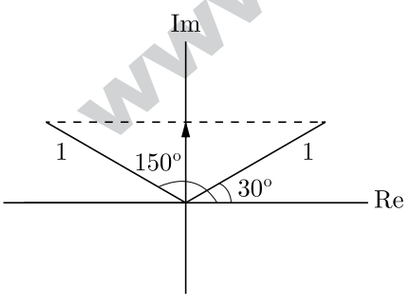
Sol. 51 Correct option is (A).
Given transformer circuit is



By Balancing mmf equation, we have

$$N_1 I_1 = N_2 I_2 + N_3 I_3$$
$$100 \times I_1 = 50 \times 2\angle 30^\circ + 50 \times 2\angle 150^\circ$$
$$100 I_1 = 100\angle 30^\circ + 100\angle 150^\circ$$
$$I_1 = 1\angle 30^\circ + 1\angle 150^\circ$$

The phasor plot for the current is



Hence, we get

$$I_1 = 1\angle 90^\circ$$

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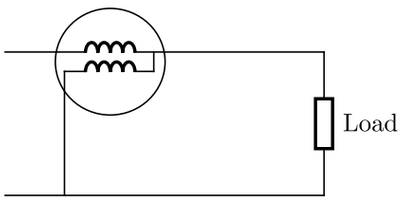
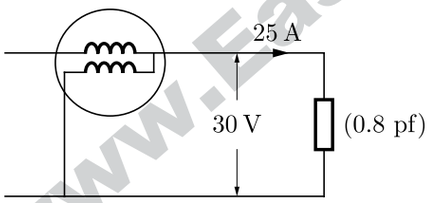
Q. 52 The coils of a wattmeter have resistance 0.01 Ω and 1000 Ω; their inductance may be neglected. The wattmeter is connected as shown in the figure, to measure the power consumed by a load, which draws 25 A at power factor 0.8. The voltage across the load terminals is 30 V. The percentage error on the wattmeter reading is_____



Sol. 52 Correct answer is 0.15

Given circuit is



Now, we have

$$R_{cc} = 0.01\,\Omega$$
$$R_{pc} = 1000\,\Omega$$
$$P_{\text{output}} = VI\cos\phi$$
$$= 25 \times 30 \times 0.8$$
$$= 600\ \text{W}$$

Current in potential coil is

$$= \frac{30}{1000} = .03\ \text{A}$$

Losses in potential coil is

$$= (0.03)^2 \times 1000$$
$$= .9\ \text{W}$$

Hence, we get

$$\text{Error} = \frac{0.9}{600} \times 100$$
$$= 0.15\%$$

Q. 53 Consider a signal defined by

$$x(t) = \begin{cases} e^{j10t} \text{for} \mid t \mid \leq 1 \\ 0 \text{ for} \mid t \mid > 1 \end{cases}$$

Its Fourier transform is

(A) $\dfrac{2\sin(\omega - 10)}{\omega - 10}$

(B) $\dfrac{2e^{j10}\sin(\omega - 10)}{\omega - 10}$

(C) $\dfrac{2\sin\omega}{\omega - 10}$

(D) $\dfrac{e^{j10\omega}2\sin\omega}{\omega}$

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Sol. 53 Correct option is (A).

Given continuous time signal,

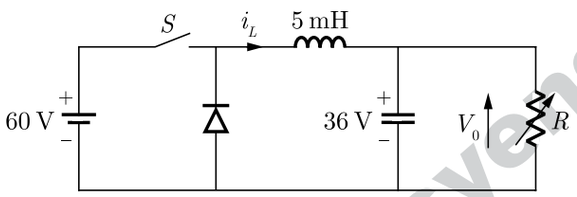
$$x(t) = \begin{cases} e^{j10t} & |t| < 1 \\ 0 & |t| > 1 \end{cases}$$

Its Fourier transform is obtained as

$$\begin{aligned} X(\omega) &= \int_{-\infty}^{\infty} x(t)\, e^{-j\omega t}\, dt \\ &= \int_{-\infty}^{-1} 0\, dt + \int_{-1}^{1} e^{j10t}\, e^{-j\omega t}\, dt + \int_{1}^{\infty} 0\, dt \\ &= \int_{-1}^{1} e^{-j(\omega-10)t}\, dt \\ &= \frac{e^{-j(\omega-10)t}}{-j(\omega-10)}\Bigg|_{t=-1}^{t=1} \\ &= \frac{e^{-j(\omega-10)1} - e^{j(\omega-10)}}{-j(\omega-10)} \\ &= \frac{2\left(e^{j(\omega-10)}\, e^{-j(\omega-10)}\right)}{(\omega-10)2j} \end{aligned}$$

Hence, $$X(\omega) = \frac{2\sin(\omega-10)}{\omega-10}$$

Q. 54 A buck converter feeding a variable resistive load is shown is the figure. The switching frequency of the switch S is 100 kHz and the duty ratio is 0.6. The output voltage V_0 is 36 V. Assume that all the components are ideal, and that the output voltage is ripple-free. The value of R (in Ohm) that will make the inductor current (i_L) just continuous is _____



Sol. 54 Correct answer is 2480 to 2520.

Q. 55 The following discrete-time equations result from the numerical integration of the differential equations of an undamped simple harmonic oscillator with state variables x and y. The integration time step is h.

$$\frac{x_{k+1} - x_k}{h} = y_k$$

$$\frac{y_{k+1} - y_k}{h} = -x_k$$

For this discrete-time system, which one of the following statements is TRUE?

(A) The system is not stable for $h > 0$

(B) The system is stable for $h > \frac{1}{\pi}$

(C) The system is stable for $0 < h < \frac{1}{2\pi}$

(D) The system is stable for $\frac{1}{2\pi} < h < \frac{1}{\pi}$

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Sol. 55 Correct option is (A).

Here, integration time step is h, so

$$x_{k+1} = x_k + h$$

and $$y_{k+1} = y_k - hx_k \quad ...(1)$$

Again, we may write

$$y_k = \frac{x_{k+1} - x_k}{h}$$

Substituting value of y_k in equation (1), we get

$$y_{k+1} = \frac{x_{k+1} - x_k}{h} - hx_k$$

$$= \frac{h + x_k - x_k}{h} - hx_k$$

$$= 1 - hx_k$$

$$= -hx_k + 1$$

Now, we form the Routh array for the above equation

s^1	$-h$	0
s^0	1	0

Hence, according to Routh-Hurwitz criterion, system is stable for

$$-h > 0$$

or $$h < 0$$

Thus, system is not stable for $h > 0$.

END OF THE QUESTION PAPER

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ANSWER KEY

General Aptitude									
1	2	3	4	5	6	7	8	9	10
(D)	(C)	(C)	(C)	(C)	(B)	(A)	(8)	(B)	(A)

Electrical Engineering									
1	2	3	4	5	6	7	8	9	10
(B)	(A)	(C)	(B)	(B)	(B)	(178.8)	(246 to 250)	(1.245)	(0.75)
11	12	13	14	15	16	17	18	19	20
(B)	(11.95)	(B)	(A)	(D)	(A)	(C)	(A)	(B)	(401.69)
21	22	23	24	25	26	27	28	29	30
(B)	(A)	(0.241)	(C)	(0)	(0.17)	(30)	(A)	(D)	(0.71)
31	32	33	34	35	36	37	38	39	40
(A)	(D)	(B)	(–48 to –46)	(D)	(1.913)	(A)	(A)	(61.52)	(0)
41	42	43	44	45	46	47	48	49	50
(A)	(1.65)	(A)	(B)	(136.36)	(A)	(190 to 192)	(0.75)	(47.5)	(A)
51	52	53	54	55					
(A)	(0.15)	(A)	(2480 to 2520)	(A)					

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